# JACK PINE SEED DISPERSAL FROM SLASH AND SEEDLING PERFORMANCE ON PREPARED SEEDBEDS

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## ABSTRACT

Studies on the periodicity of jack pine (*Pinus banksiana* Lamb.) seed dispersal from slash and its effect on germination and seedling survival determined by direct seeding were carried out over a 4-year period in south-eastern Manitoba. Seed dispersal from slash began in May, increased through June, and by the end of August, 87-95% of the first-year cumulative total had been dispersed. Total first-year seed dispersal ranged from 7.72-10.76 kg/ha, but this represented only about 50% of total seed available. Cones from ground level to 18 cm above ground represented 75-80% of the total number of cones on the area and accounted for 92-94% of the total first-year seedfall. Spot seeding on prepared seedbeds showed that late May to mid-July was the optimum time for germination and seedling establishment.

## RESUME

Durant quatre ans, on a étudié dans le sud-est du Manitoba la périodicité de la dissémination des semences du pin gris (*Pinus banksiana* Lamb.) à partir de rémanents et son effet sur la germination et la survie des semis. La dissémination débute en mai, augmente jusqu'à la fin de juin, et, avant la fin d'août, s'élève à 87-95% du total cumulatif de l'année. Ce total varie entre 7,72 et 10,76 kg/ha, mais il ne représente que la moitié des semences disponibles. Les cônes situés entre le niveau du sol et 18 cm au-dessus comptent pour 75 à 80% de tours les cônes tombés et fournissent 92 à 94% de toutes les semences disséminées dans l'année. L'ensemencement sur placeaux montre que la période optimale pour la germination et l'implantation des semis se situe entre la fin de mai et la mi-juillet.

# CONTENTS


| | Page |
|---|---|
| **INTRODUCTION** | 1 |
| **STUDY AREA** | 1 |
| **METHODS** | 1 |
| Scarification and slash distribution | 1 |
| Determination of quantity and time of seed dispersal from slash-borne cones | 1 |
| Assessment of seed germination and seedling mortality following spot seeding | 2 |
| **RESULTS** | 3 |
| Quantity of seed from slash-borne cones | 3 |
| Periodicity of seed dispersal | 3 |
| Seed germination and seedling mortality following direct seeding | 5 |
| **DISCUSSION AND RECOMMENDATIONS** | 5 |
| **REFERENCES** | 12 |


## FIGURES


1. First- and second-year cumulative jack pine seed dispersal per ha from slash on 1964-67 clear-cut areas. 4
2. First- and second-year percentage germination and mortality by seeding date, weekly rainfall, and average weekly maximum air temperature, 1965-68 clear-cut areas. 8
3. First- and second-year cumulative percentage germination and mortality by weekly intervals, 1965-68 clear-cut areas. 10


## TABLES


1. Stand characteristics on study areas prior to logging 2
2. The effects of settling and snow compaction on distribution of cones in three height levels of slash 3
3. Percentage of jack pine seed contributed from three height levels of slash during the first year following logging 5
4. Percentage of jack pine cones that were open, partially open, or closed after 1 and 2 years, by three height levels of slash 6
5. Germination and mortality 1 to 3 years after seeding 7
6. Seasonal rainfall 7
7. Average height, growth, and secondary branching of 2-year-old seedlings 7
8. First- and second-year germination and mortality by month of seeding, 1965-68 clear-cut areas 11

## INTRODUCTION

Natural regeneration of jack pine (*Pinus banksiana* Lamb.) after clear-cutting is commonly obtained through scarification and slash redistribution over the exposed mineral soil. Seed dispersal begins when cone temperatures reach or exceed 50°C, dissolving the resin bond of the scales (Cameron 1953). In southeastern Manitoba air temperatures needed to heat the cone surfaces to this level usually do not occur until midsummer; therefore many cones do not release seed until July or later. It is believed that seedlings germinating early in the growing season have a better chance of survival than those germinating late in summer. More information is required on seed dispersal from cone-bearing slash, when seed germinates, and how well the seedlings survive. This information could lead to modifications of slash disposal treatments to provide for either earlier or later dispersal of seed.

This report presents the results of studies carried out from 1964 to 1970 to determine (1) the amount of seed contained in slash-borne cones, (2) the periodicity and rate of seed dispersal, and (3) the time of seed germination and its effect on seedling mortality, as determined from direct seeding.

## STUDY AREA

The study area is located in the Sandilands Forest Reserve about 100 km southeast of Winnipeg. It is part of the Rainy River (L.12) Section of the Great Lakes-St. Lawrence Forest Region (Rowe 1972). The topography is flat to gently rolling, and sandy soil textures predominate in the jack pine sites. Elevation ranges from 270 to 400 m. The climate is continental with high summer and low winter temperatures. Average annual precipitation from 1941 to 1970 was 58 cm, with about 66% of this occurring as rainfall from May to September (Atmospheric Environment Service 1973).

## METHODS

### Scarification and slash distribution

Five individual jack pine stands ranging in age from 55 to 80 years were winter-logged in separate years between 1964 and 1968. Prior to logging, seedbeds were mechanically prepared with a middlebuster plow drawn behind a tractor. This type of scarification created furrows 90-120 cm in width and 5-13 cm deep, with the overturned sod forming a ridge 30-60 cm in width on each side of the furrow. The resulting seedbeds consisted of approximately 25% mineral soil in the trough and 20% mineral soil on the ridge, with 55% of the area undisturbed. Slash was lopped and scattered by hand during the logging operation, and shortly thereafter additional scattering was done to ensure an even slash distribution on the area.

### Determination of quantity and time of seed dispersal from slash-borne cones

Studies to determine the amount and periodicity of seed dispersal were carried out on the first four areas clear-cut between 1964 and 1967 (Table 1). Fifty transects 22 m in length and divided into eleven 2×2 m quadrats were systematically established on each area. The total number of cones per hectare was determined by making a total cone count on the first quadrat of each transect. During the second year a total cone count was made on 25 quadrats to determine the effect of snowfall on slash composition. Cones were grouped into three height classes (0-18.0 cm, 18.1-30 cm, and 30.1+ cm above ground) and were classified as open (when 75% or more of the cone scales had opened), partially open (when one

**Table 1. Stand characteristics on study areas prior to logging**

| Year of cut | Age (yr) | Trees[1] (no./ha) | Basal area[1] ($m^2$/ha) | Merchantable volume ($m^3$/ha) | Cones/ha (average) |
|---|---|---|---|---|---|
| 1964 | 55-70 | 484 | 12 | 99 | 213 132 |
| 1965 | 55-60 | 662 | 19 | 197 | 279 487 |
| 1966 | 55-80 | 347 | 13 | 127 | 222 406 |
| 1967 | -[2] | 646 | 16 | 79 | 289 107 |

[1] Data based on jack pine ≥10.2 cm diameter at breast height.

[2] No data available.

or more scales up to 75% had opened), and closed.

Approximately every 28 days, as weather and work schedules permitted, one quadrat from quadrats 2-11 within each transect was randomly chosen and the four cones closest to the center of the quadrat in each height class were sampled. Only open and partially open cones were collected. Where there was not a sufficient number of cones in each height class to provide four sample cones, a sample was taken outside the quadrat to make up the remainder. If no cones were present in one of the height classes within the quadrat, then no sample was taken outside the quadrat.

Cones were sealed in polyethylene bags and taken to the laboratory for the seed dispersal counts. Indentations on the top of the cone scale clearly indicated whether a seed had been dispersed or was not present before the scale opened. This method was proven in the laboratory by heating 300 closed cones in an oven, estimating seed dispersal from indentations, and then comparing the estimate (significant at the 99% confidence level) with the actual seed dispersal from each cone.

Mean seed dispersal of the cones collected in each height class was determined, and this value was multiplied by the number of cones per hectare (determined by the total cone count made on the first 50 quadrats) either open or partially open in each class during the collection period to obtain the total number of seeds. Kilograms per hectare were then calculated on the basis of 288 800 seeds per kilogram (Schopmeyer 1974, p. 622).

## Assessment of seed germination and seedling mortality following spot seeding

Studies to determine the effect of date of seed germination on seedling survival were carried out on the three areas used for the seed dispersal studies in 1965-67 and on an additional area clear-cut in the winter of 1968. Spot seeding on each area was carried out on 10 blocks of 12 quadrats with each seeded quadrat measuring 44 × 44 cm in size. The quadrats were confined to the trough portion of the seedbed created by the middlebuster plow; all slash and debris was removed prior to quadrat establishment. The 1965-67 areas were classified as fresh habitats and the 1968 area as a dry habitat (Mueller-Dombois 1964). At 2-week intervals beginning early in May and ending in October, one quadrat from each block was randomly chosen and sown with 50 seeds, and then lightly covered with soil. Seed viability for the 4 years of seeding from 1965-68 ranged from 86 to 97%. The seeds were pretreated with Arasan (a fungicide), Endrin (an animal repellent), and aluminum flakes, a lubricant used to facilitate seed flow in mechanical seeders.

**Table 2. The effects of settling and snow compaction on distribution of cones in three height levels of slash**

| Year of cut | | Height above ground 0-18.0 cm (% cones) | 18.1-30.0 cm (% cones) | 30.1+ cm (% cones) | Total (cones/ha) | Cones (no.) |
|---|---|---|---|---|---|---|
| 1964 | Spring 1964 | 79 | 15 | 6 | 189 723 | 3 839 |
| | Spring 1965 | 88 | 9 | 3 | 259 949 | 2 630 |
| 1965 | Spring 1965 | 75 | 17 | 8 | 259 406 | 5 249 |
| | Spring 1966 | 85 | 7 | 8 | 319 648 | 3 234 |
| 1966 | Spring 1966 | 80 | 10 | 10 | 235 536 | 4 766 |
| | Spring 1967 | 90 | 7 | 3 | 196 148 | 1 984 |
| 1967 | Spring 1967 | 76 | 16 | 8 | 263 903 | 5 340 |
| | Spring 1968 | 80 | 10 | 10 | 339 515 | 3 435 |

The 10 blocks of 12 quadrats on the 1966-68 areas were enclosed by a fence constructed of 76-cm high sheets of galvanized metal placed 15 cm into the ground to keep out rodents; enclosures were trapped prior to seeding. The fenced area measured about 14 × 14 m and the fence was placed so that no shade fell on the seed spots. Weekly germination counts were begun 1 week after seeding and continued into the fall of the first year. Germination and survival counts were made at 2-week intervals during the second and third years.

Each new germinant was marked with a colored plastic skewer, with different colors denoting weekly germination periods, and the date of germination was recorded. As seedling mortality occurred, dead seedlings were marked with a red skewer and the date recorded. Daily maximum and minimum air temperatures were recorded with a thermograph housed in a shelter 1 m above ground. Weekly rainfall was measured with three Beal rain gauges.

## RESULTS

### Quantity of seed from slash-borne cones

Total seedfall the first summer after logging ranged from 7.72 kg/ha in 1966 to 10.76 kg/ha in 1967 (Fig. 1) from cutovers containing 235 536 and 263 903 cones/ha, respectively, (Table 2). Seedfall on the 1964 and 1965 clear-cut areas, with 189 723 and 259 406 cones/ha, respectively, was slightly more than 10 kg/ha and thus was similar to the 1967 clear-cut area. Cones in the 0-18 cm height level accounted for 92-94% of the total seed dissemination during the first year after logging (Table 3). This height level, however, also contained 75-80% of the total number of cones; slash settling and snow compaction increased this to 80-90% in the second spring (Table 2). Seed dispersal during the second summer following logging was negligible and was detected only on the 1965 and 1967 areas. (Fig. 1).

### Periodicity of seed dispersal

Seed dispersal began about the middle of May and by the end of the month 9-18% of the total first-year amount had fallen in individual years; this increased cumulatively to 34-45% at the end of June, 50-82% at the end of July, and 87-95% at the end of August (Fig. 1). Seed dispersal from 1964 to 1966 followed the same

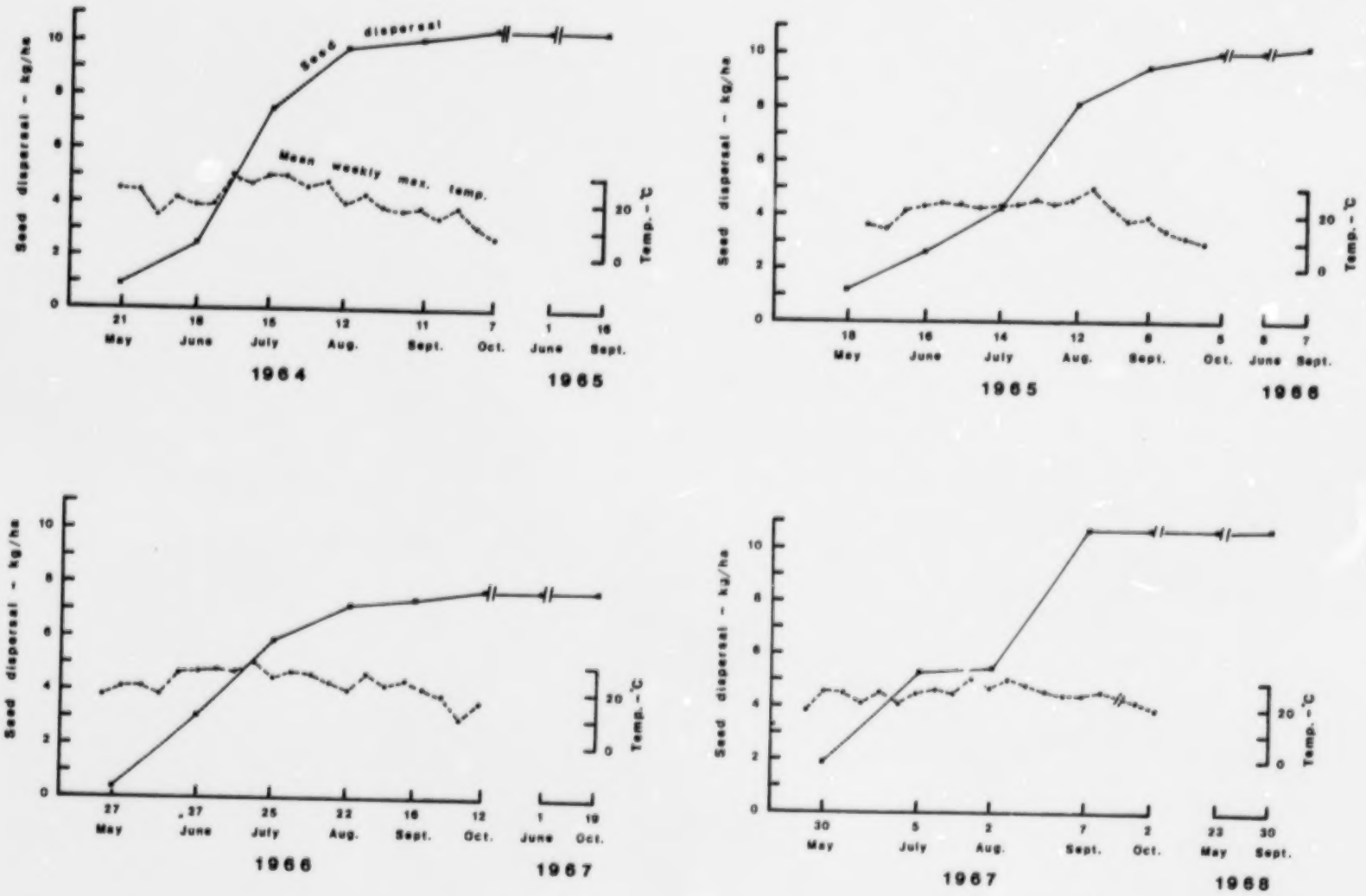


**Figure 1. First- and second-year cumulative jack pine seed dispersal per ha from slash on 1964-67 clear-cut areas.**

**Table 3. Percentage of jack pine seed contributed from three height levels of slash during the first year following logging**

| Year of cut | Height above ground | | | Seeds (no.) |
|---|---|---|---|---|
| | 0-18.0 cm | 18.1-30.0 cm | 30.1 + cm | |
| 1964 | 92 | 7 | 1 | 18 019 |
| 1965 | 93 | 6 | 1 | 11 997 |
| 1966 | 94 | 4 | 2 | 10 342 |
| 1967 | 93 | 7 | <1 | 10 078 |

general trend, with a steady cumulative increase each month. In 1967, however, July 5 to August 2 dispersal was minimal, but dispersal increased rapidly to September 7. Smaller amounts of seed were released from September through October. Air temperatures (1 m above ground level) of at least 26.6°C were indicative of a more rapid opening of cones and dissemination of seed; jack pine is similar in this respect to lodgepole pine (*Pinus contorta* Dougl. var *latifolia* Engelm.) (Crossley 1956).

The percentage of open cones in the 0-18 cm height level on the four cutovers ranged from 34 to 41% at the end of the first summer and from 40 to 62% at the end of the second summer (Table 4). Consequently, 38-60% of the cones in this height level were still closed and a substantial amount of seed was still available to be disseminated in later years.

### Seed germination and seedling mortality following direct seeding

First-year germination ranged from 9 to 28% of the total number of viable seeds sown and additional germination ranging from 4 to 17% occurred during the second year for all seeding periods (Table 5). Even the earliest sowings in May did not germinate entirely within the same year; seeds from this sowing period remained dormant and germinated in the second year (Fig. 2).

The lower germination and higher mortality rates in 1967 are attributed to drought; May-October precipitation was only 66% of the 30-year annual average (Table 6). First-year germination of the 1967 area was only 9%, and mortality of these germinants to the third year was 79% (Table 5). Second-year germination on the 1966 area was 5% and mortality was 84% to the second year (Table 5). Seedlings established in this year had the smallest average height and growth and the fewest number of secondary branches (Table 7).

First-year germinants on the 1965-68 clearcut areas began to appear between May 24 and July 4; germination in the second year began somewhat earlier and varied from May 21 to May 30 (Fig. 3). Little germination occurred after the end of August except during the first year on the 1968 area, when there was a further 8% increase from August 27 to October 1. The most favorable seeding times were May, June, and the first half of July. During this period, approximately 10% or more of the viable seeds sown germinated and became established. The ratio of seeds to surviving seedling steadily increased from May to October, and seeding efficiency decreased (Table 8).

## DISCUSSION AND RECOMMENDATIONS

About 50% of the cones were still closed at the end of the second summer after logging, and little or no seed dispersal was detected during the second year, although some cone opening did occur. This anomaly is attributed to the difficulty of determining if a seed had

**Table 4. Percentage of jack pine cones that were open, partially open, or closed after 1 and 2 years, by three height levels of slash**

| Area | Sample date | 0-18.0 cm | | | | 18.1-30.0 cm | | | | 30.1+ cm | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Open[1] | Partially open[2] | Closed | Cones (no.) | Open | Partially open | Closed | Cones (no.) | Open | Partially open | Closed | Cones (no.) |
| 1964 | Oct. 7, 1964 | 34 | 12 | 54 | 1148 | 8 | 9 | 83 | 903 | 3 | 4 | 93 | 531 |
| | Sept. 16, 1965 | 58 | 7 | 35 | 373 | 26 | 10 | 64 | 288 | 9 | 3 | 88 | 140 |
| 1965 | Oct. 5, 1965 | 36 | 6 | 58 | 1170 | 8 | 6 | 86 | 912 | 3 | 2 | 95 | 578 |
| | Sept. 7, 1966 | 51 | 10 | 39 | 395 | 14 | 12 | 74 | 280 | 5 | 8 | 87 | 128 |
| 1966 | Oct. 12, 1966 | 34 | 8 | 58 | 1125 | 6 | 6 | 88 | 920 | 2 | 2 | 96 | 768 |
| | Oct. 19, 1967 | 40 | 5 | 55 | 367 | 11 | 4 | 85 | 227 | 2 | 1 | 97 | 172 |
| 1967 | Oct. 2, 1967 | 41 | 7 | 52 | 946 | 9 | 4 | 87 | 757 | 1 | 1 | 98 | 599 |
| | Sept. 30, 1968 | 62 | 3 | 35 | 372 | 15 | 5 | 80 | 292 | 2 | 2 | 96 | 224 |

[1] 75% or more of the cone scales opened.

[2] One or more cone scales up to 75% opened.

**Table 5. Germination and mortality 1 to 3 years after seeding**

| Year of cut | Viable seeds sown (no.) | Years after seeding | % germination | % cumulative mortality | | |
|---|---|---|---|---|---|---|
| | | | | 1st-yr | 2nd-yr | 3rd-yr |
| 1965 (fresh site) | 5700 | 1 | 19 | 15 | 25 | 28 |
| | | 2 | 17 | 4 | 11 | -[1] |
| | | 3 | 0 | 0 | 0 | 0 |
| 1966 (fresh site) | 5454 | 1 | 18 | 16 | 43 | 68 |
| | | 2 | 5 | 56 | 84 | - |
| | | 3 | 0 | 0 | 0 | 0 |
| 1967 (fresh site) | 5820 | 1 | 9 | 57 | 71 | 79 |
| | | 2 | 13 | 34 | 59 | - |
| | | 3 | 1 | 38 | - | - |
| 1968 (dry site) | 5136 | 1 | 28 | 39 | 55 | 57 |
| | | 2 | 4 | 38 | 49 | - |
| | | 3 | - | - | - | - |

[1] Dash indicates no data available.

**Table 6. Seasonal rainfall**

| Year of cut | Period | Precipitation (mm) | % of 30-yr annual average precipitation (May-Oct.) |
|---|---|---|---|
| 1965 | May 19 - Sept. 28 | 374 | 97 |
| 1966 | May 17 - Oct. 18 | 406 | 106 |
| 1967 | May 9 - Oct. 10 | 254 | 66 |
| 1968 | May 7 - Oct. 10 | 535 | 139 |
| Average annual precipitation | May 1 - Sept. 30 | 387 | |

**Table 7. Average height, growth, and secondary branching of 2-year-old seedlings**

| Year of cut | Seedlings (no.) | Average height (cm) | Average growth 2nd yr (cm) | Secondary branching (% of seedlings) |
|---|---|---|---|---|
| 1965 | 782 | 12.7 | 7.7 | 79 |
| 1966 | 317 | 10.3 | 6.3 | 75 |
| 1967 | 103 | 6.3 | 4.3 | 45 |
| 1968 | 588 | 13.3 | 8.8 | 76 |

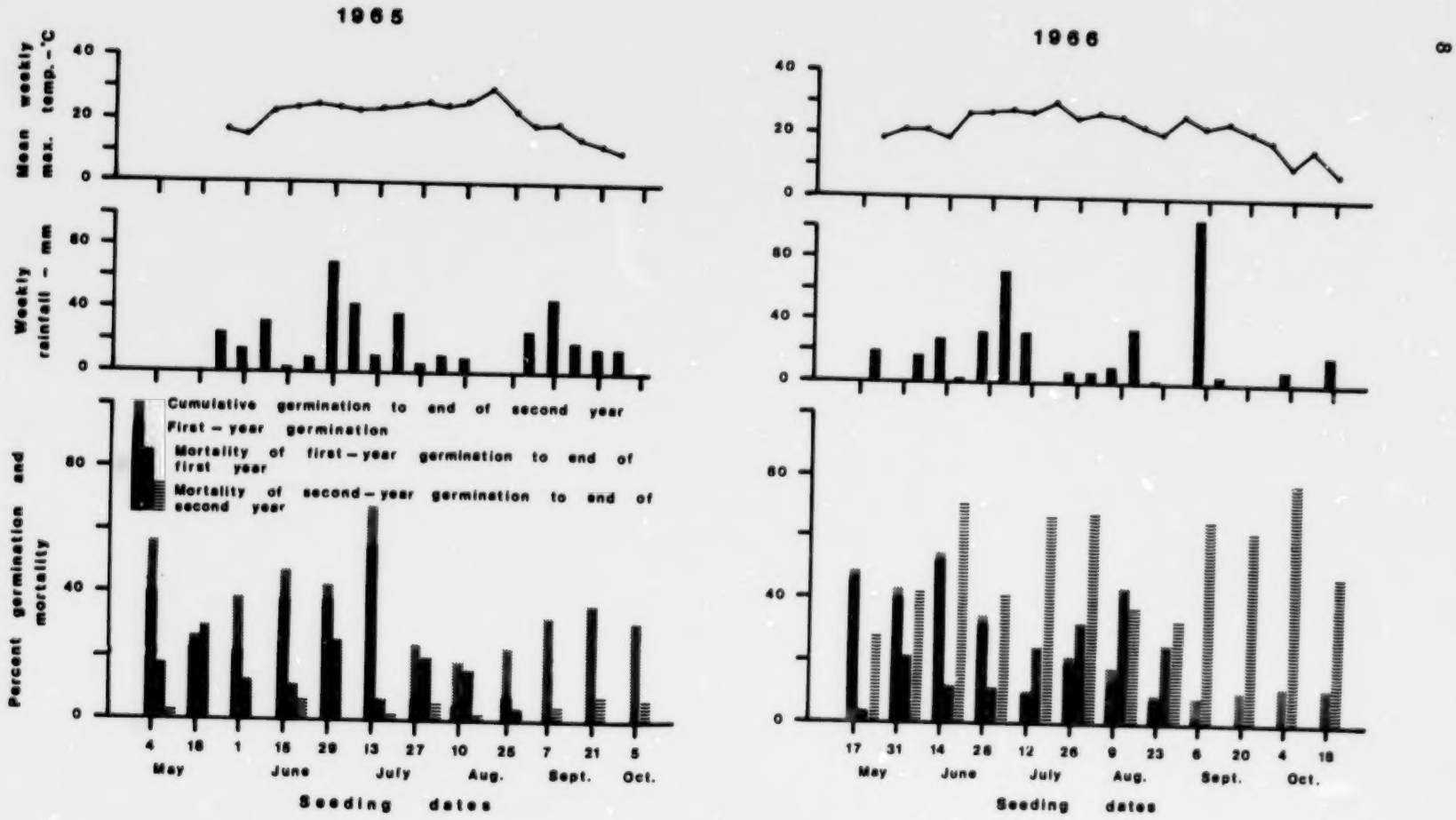
1965
1966
Mean weekly max. temp. - °C
Weekly rainfall - mm
Percent germination and mortality
Cumulative germination to end of second year
First – year germination
Mortality of first – year germination to end of first year
Mortality of second – year germination to end of second year
4 18 1 15 29 13 27 10 25 7 21 5
May June July Aug. Sept. Oct.
17 31 14 28 12 26 9 23 6 20 4 18
May June July Aug. Sept. Oct.
Seeding dates
Seeding dates

**Figure 2. First- and second-year percentage germination and mortality by seeding date, weekly rainfall, and average weekly maximum air temperature, 1965-68 clear-cut areas.**

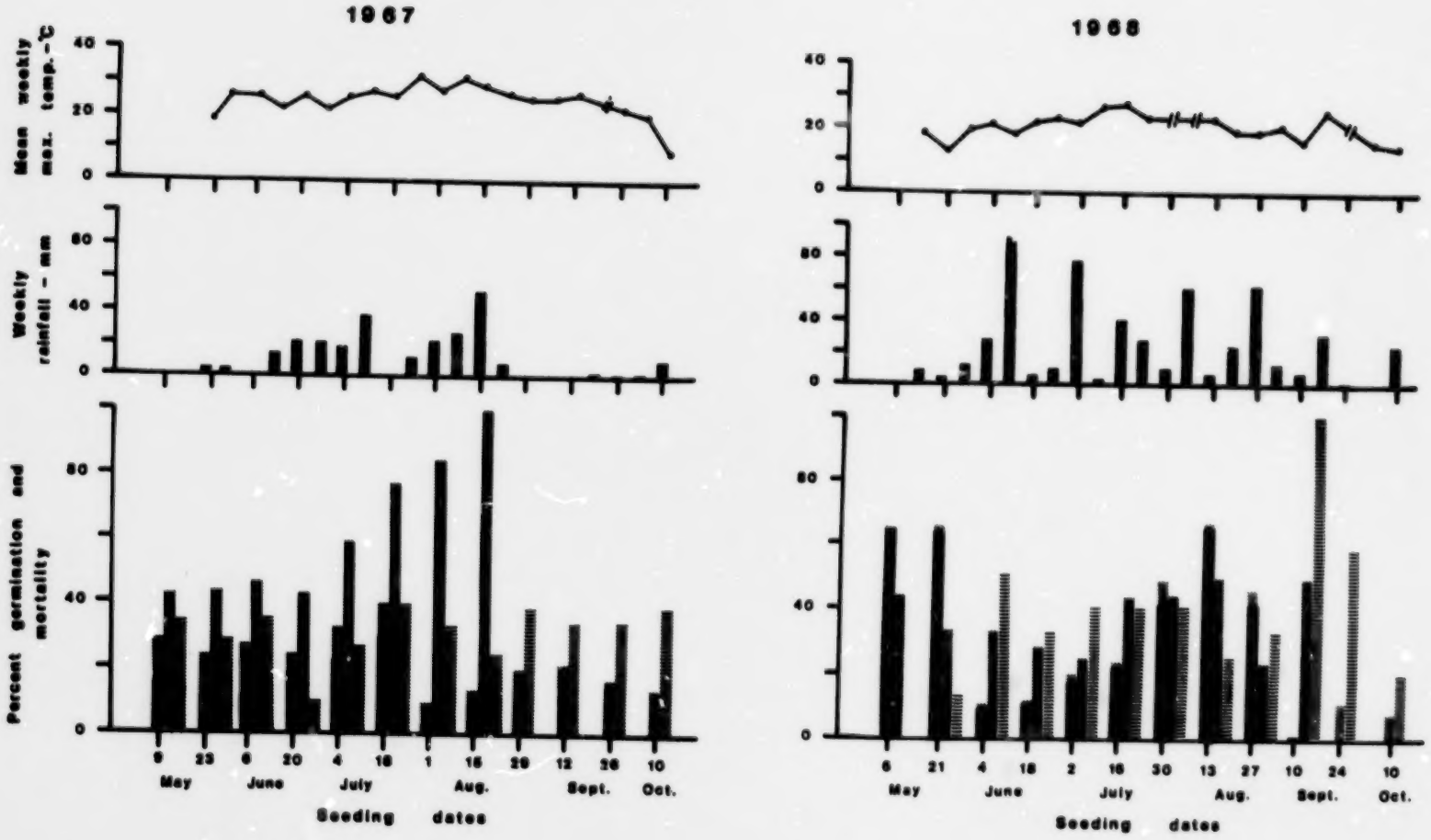
1967
1968
Mean weekly max. temp. - °C
Weekly rainfall - mm
Percent germination and mortality
9 23 6 20 4 18 1 15 29 12 26 10
May June July Aug. Sept. Oct.
Seeding dates
6 21 4 18 2 16 30 13 27 10 24 10
May June July Aug. Sept. Oct.
Seeding dates

**Figure 2. Continued.**

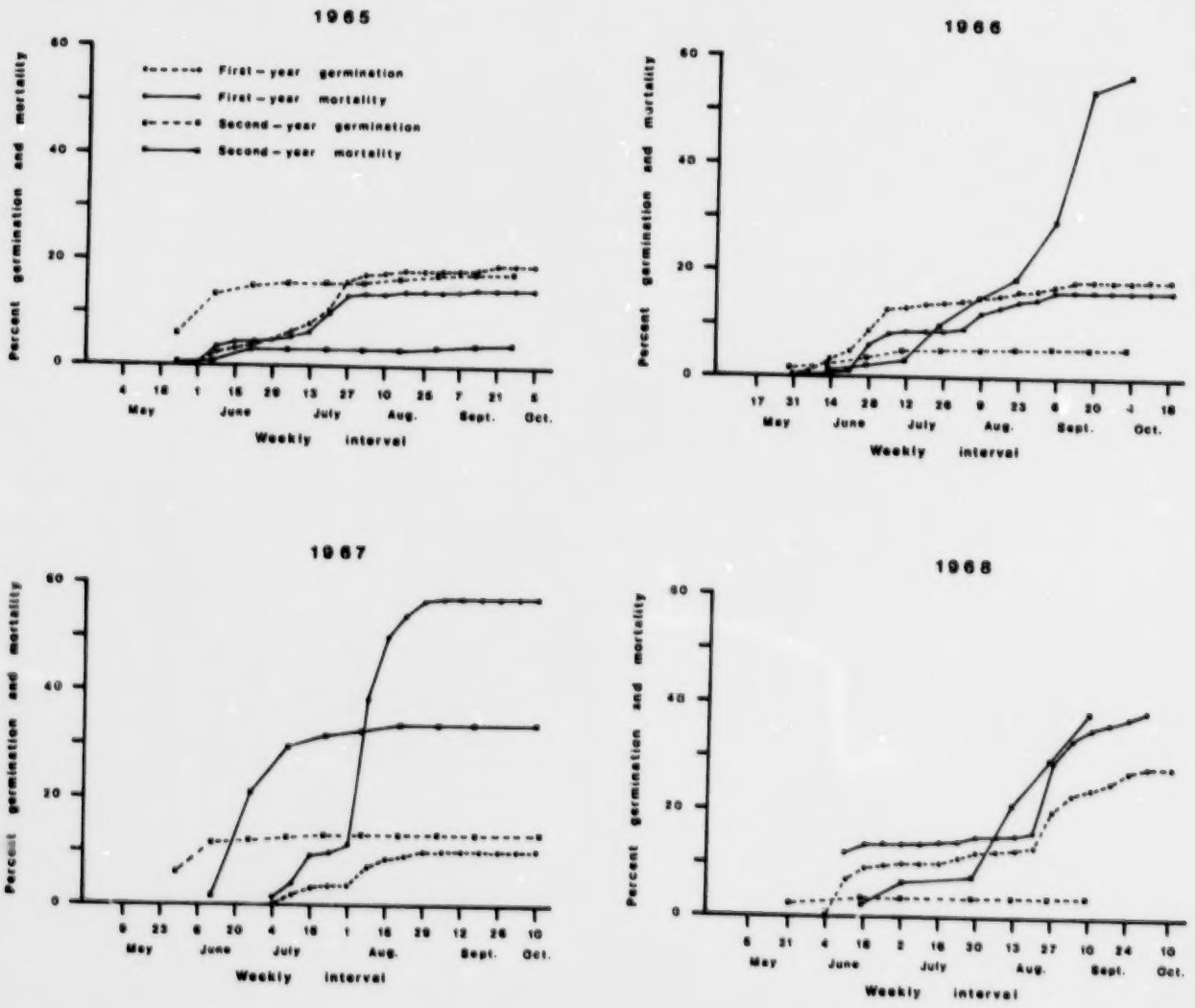


**Figure 3. First- and second-year cumulative percentage germination and mortality by weekly intervals, 1965-68 clear-cut areas.**

**Table 8. First- and second-year germination and mortality by month of seeding, 1965-68 clear-cut areas**

| | May | June | July | August | September | October |
|---|---|---|---|---|---|---|
| % germination | 44 | 33 | 32 | 24 | 18 | 16 |
| % mortality | 27 | 19 | 34 | 31 | 26 | 30 |
| Ratio of seeds to surviving seedlings | 3.1 | 3.8 | 4.6 | 6.0 | 7.7 | 9.2 |
| Viable seeds sown (no.) | 3684 | 4159 | 4112 | 4169 | 3684 | 2296 |

been present in the cone, as the cones had already been considerably affected by the weather. First-year seed dispersal was 7.72-10.76 kg/ha and this figure could increase by 100% as the remaining cones open. This is greater than the 14.46 kg/ha and 15.13 kg/ha obtained by Eyre and LeBarron (1944), when all the cones were picked from an acre of a well-stocked, mature stand in Minnesota. Noakes (1946) reported that a lopped and scattered cutover in Ontario contained 741 000-988 000 cones per hectare, which is more than twice the number estimated in this study (Table 2), and the amount of seeds in those stands would presumably also be double. Hennessey[1, 2, 3] reported an average per-hectare cone count ranging from 264 397 to 903 562 for five different locations in central Saskatchewan; two areas in southeastern Manitoba had averages of 172 970 and 289 107, respectively, and a third area in west-central Manitoba had an average of 348 411.

As periodic cone collections were made, it was observed that most cone opening and seed dispersal occurred from those cones resting immediately on the ground surface, but no attempt was made to separate these cones from others in the 0-18 cm level. In a study of cone opening and seed dispersal from cones placed at 0, 10, and 23 cm above mineral soil, Bruce and Sims (1970) reported that May-to-October cone opening in the first year averaged 92, 17, and 3% at the respective levels; seed dispersed per cone was 28.0, 1.0, and 0.6.

May and June were the two most favorable months for germination and seedling establishment. This is in agreement with the findings of Cayford (1961) and Sims (1970). July and August was the period least favorable for germination and seedling survival; however, the large amount of seed available in the slash ensures that areas can be successfully regenerated when scarified at this time[2, 3, 4]. The

[1] Hennessey, G.R. Scarifying cutover jack pine stands with barrels and anchor chains in Saskatchewan. 1968. Can. Dep. For. Rural Dev., For. Br. Unpubl. Intern. Rep. MS-64.

[2] Hennessey, G.R. Scarifying cutover jack pine stands with barrels and anchor chains, Manitoba and Saskatchewan. 1969. Can. Dep. Fish. For., For. Br. Unpubl. Intern. Rep. MS-94.

[3] Hennessey, G.R. Scarifying cutover jack pine stands with barrels and anchor chains, Manitoba and Saskatchewan. 1970. Can. Dep. Fish. For., For., Serv. Unpubl. Intern. Rep. MS-104.

[4] Kolabinski, V.S. Unpublished file report on scarifying recently cutover jack pine stands with barrels and anchor chains in Saskatchewan. 1974. Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta.

Prince Albert Pulp Company is currently using this technique with good results on an operational basis in central Saskatchewan (Ball 1975). All seed sown in October and most sown in September germinated during the following year, but seedling establishment for this seeding period was the poorest for the entire year. This is in contrast to the findings of Cayford and Dobbs (1967), who suggested that autumn seeding on dry and fresh sites might be preferable over spring seeding.

Kolabinski[5] reported good seedling establishment during the first and second years following scarification; ingress from the third to fifth years added few seedlings and indicated a greatly reduced seed supply or receptive seedbed. An inadvertent second scarification on one area four years after initial treatment, however, produced a number of fifth-year germinants. This was attributed to reexposure of buried cones, but further slash breakdown may be a possible reason.

If areas cannot be scarified in the same year that they are cut, excessive seed loss should be prevented. Large, unbroken, cone-bearing branches and noncommercial tops should be left on the area. This would maintain a supply of cones 18 cm or more above the ground and minimize cone opening. Where mechanical tree harvesters that cut and delimb on-site are used, scarification should not be delayed as the slash is immediately broken.

Flails for delimbing trees off-site are also commonly used in current logging operations. This practice may remove too many cones from the area to ensure natural regeneration. A pretreatment cone survey of distribution and density should be made. Subsequent monitoring of regeneration may then determine the actual number of cones and the intensity of scarification required to ensure successful natural regeneration.

## REFERENCES


Atmospheric Environment Service. 1973. Canadian normals. Vol. 2. Precipitation, 1941-1970. Environ. Can., Atmos. Environ. Serv., Downsview, Ont.

Ball, W.J. 1975. An Appraisal of natural regeneration on scarified jack pine cutovers, Saskatchewan. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-136.

Bruce, N.G.; Sims, H.P. 1970. Site preparation essential to obtaining best results from jack pine cones. Pulp Pap. 71(14):70-72.

Cameron, H. 1953. Melting point of the bonding material in lodgepole pine and jack pine cones. Can. Dep. Res. Dev., For. Branch, For. Res. Div. Silvic. Leafl. 86.

Cayford, J.H. 1961. Broadcast seeding jack pine at weekly intervals in Manitoba. Can. Dep. For., For. Res. Branch. Tech. Note 106.

Cayford, J.H.; Dobbs, R.C. 1967. Germination and early survival of jack pine on three sites in southeastern Manitoba. Bi-mon. Res. Notes 23(1):6-7.

Crossley, D.J. 1956. The effect of crown cover and slash density on the release of seed from slash-borne lodgepole pine cones. Can. Dep. North. Aff. Nat. Res., For. Branch, For. Res. Div. Tech. Note 41.

Eyre, F.H.; LeBarron, R.K. 1944. Management of jack pine stands in the Lake States. USDA Tech. Bull. 863.


[5] Kolabinski, V.S. Unpublished file report on scarifying recently cutover jack pine stands with barrels and anchor chains in Saskatchewan. 1974. Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta.

Mueller-Dombois, D. 1964. The forest habitat types of southeastern Manitoba and their application to forest management. Can. J. Bot. 42:1417-1444.

Noakes, J.W. 1946. Effect of different methods of slash disposal on jack pine reproduction. Can. Dep. Mines Res., Land, Parks, For. Branch, Dom. For. Ser. Silvic Res. Note 78.

Rowe, J.S. 1972. Forest regions of Canada. Environ. Can., Can. For. Serv. Publ. 1300.

Schopmeyer, C.S. 1974. Seeds of woody plants in the United States. USDA For. Serv. Washington, D.C. Agric. Handb. 450.

Sims, H.P. 1970. Germination and survival of jack pine on three prepared cutover sites. Can. Dep. Fish. For., Can. For. Serv. Publ. 1283.